Oxide Fuel Fabrication Efforts at Los Alamos for the Advanced Fuel Cycle Initiative

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LWR-series of Irradiation Tests

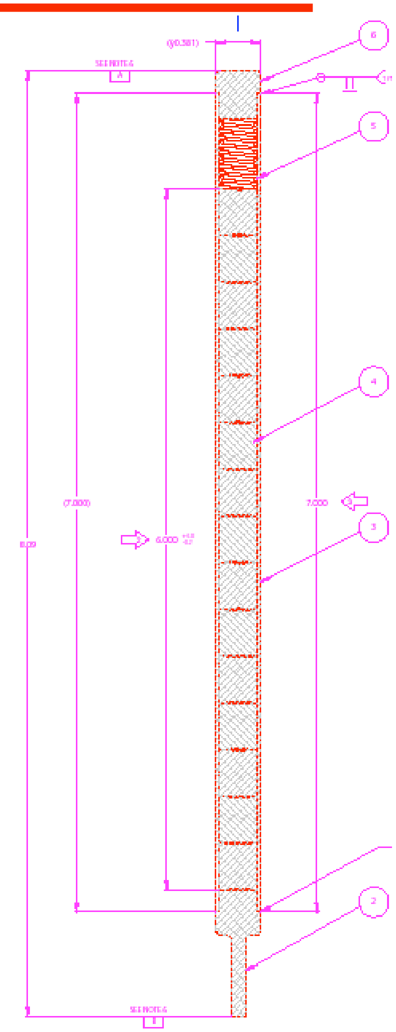
- Irradiation experiments done at ATR at INL
- Cooperative experiment among multiple DOE Labs

LWR-1 (November 2003)

Fuel ID	Description	Initial Feed	Planned Burnup (GWd/MT)
PROF-1	5% WG Pu oxide in DU oxide	WG Pu (93.8% fissile)	5,10,20
PROF-2	6.3% RG Pu oxide in DU oxide	RG Pu (~77% fissile)	5,10,20
PROF-3	6.3% RG Pu oxide w/ 0.4% Np oxide in DU oxide	RG Pu (~77% fissile)	5,10,20

LWR-1B (Proposed)

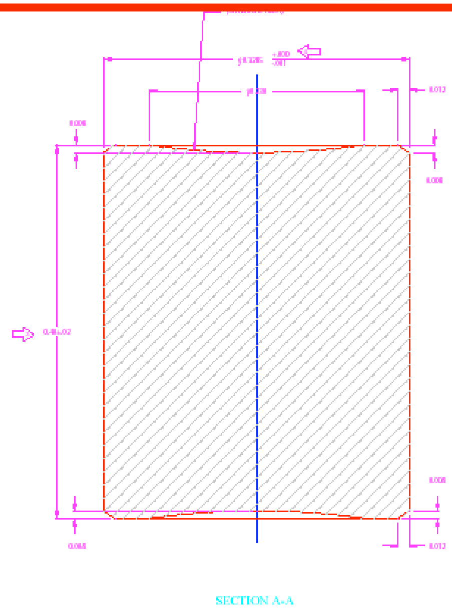
Fuel ID	Description	Initial Feed	Planned Burnup (GWd/MT)
PROF-4	6.3% RG Pu oxide w/ 0.4% Np oxide in DU oxide	RG Pu (~77% fissile)	5, 10, 20
PROF-5	Pu/Np feed from spent fuel	RG Pu, Np	5, 10, 20
PROF-6	To be determined	Tbd	Tbd

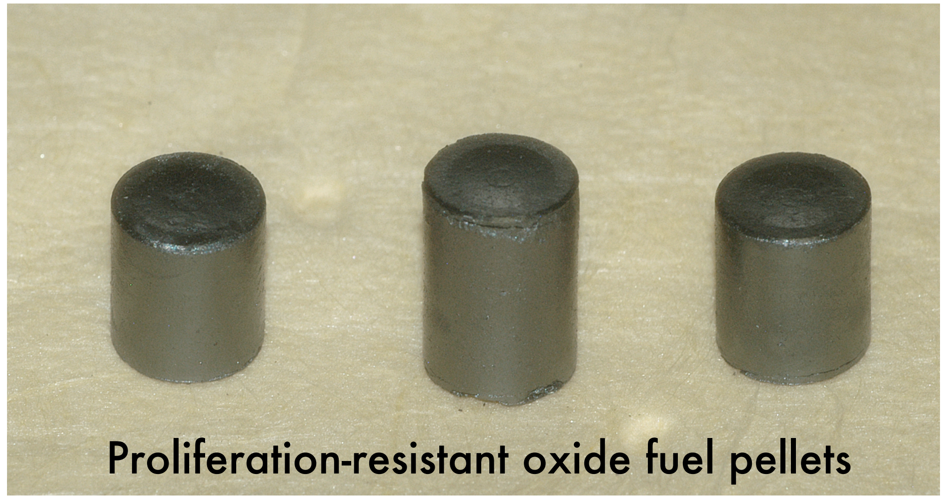


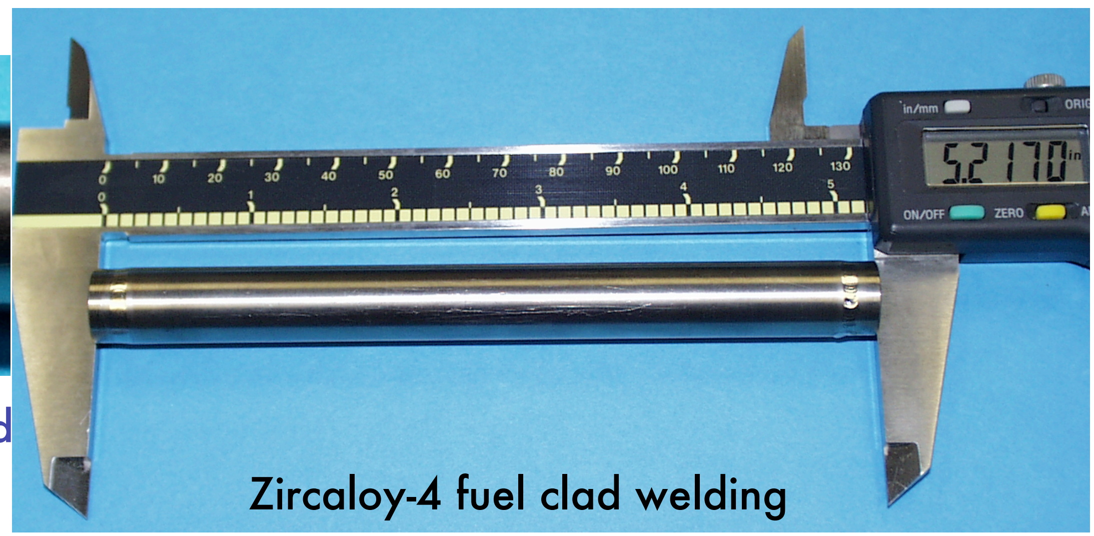
SECTION A-A

Los Alamos NATIONAL LABORATORY

LWR-1 Fabrication Efforts




Proliferation-resistant oxide fuel pellets



Zircaloy-4 fuel clad welding

- Technology needs to be demonstrated
- Infrastructure, authorization in place

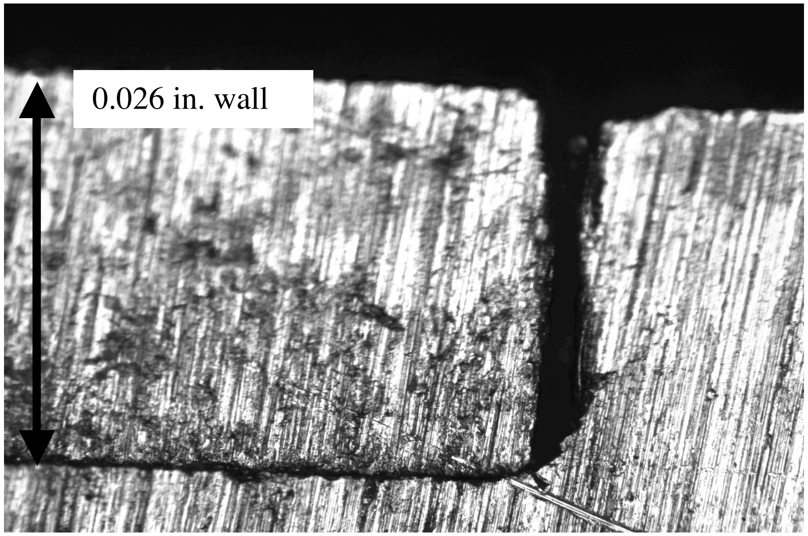
Fabrication (to date)

Composition	Status	Density (%TD) (92-96%)	Diameter (in.) (0.3265-0.3275 in.)	Length (in.) (0.350-0.450 in.)
PROF-1	Pellets for LWR-1 complete	94.0	0.340 unground	0.400
PROF-2	Fabrication parameters complete	Tbd	Tbd	Tbd
PROF-3	Fabrication parameters complete	Tbd	Tbd	Tbd

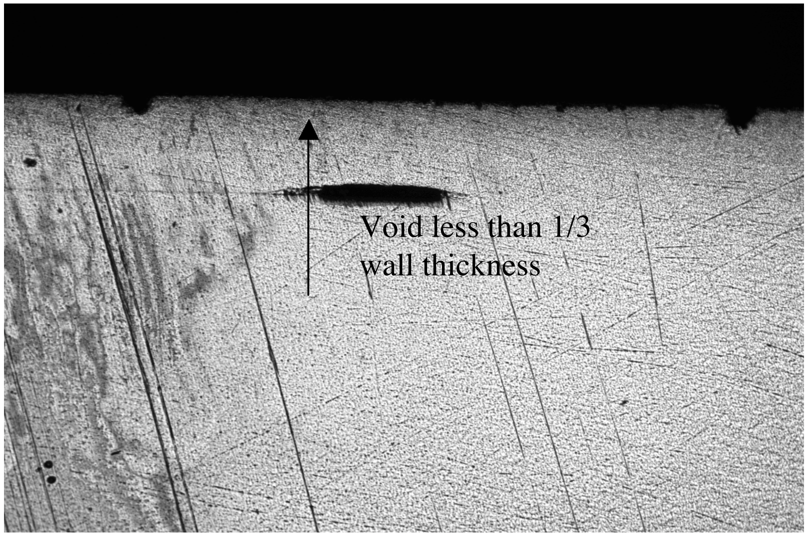
Weld Capability

- Objective: Reestablishment of a He bonding capability was needed in order to achieve insertion of oxide fuels into the ATR within time and budget constraints- He bonding at LANL allows additional time to produce the oxide fuel after fabrication of the nitride fuels.
- Constraints:
  - -Process Development
  - -Procurement of Commercially Unavailable Material/Products
  - -QA Establishment and Implementation
  - -Machining of Pin Components and Ancillary Equipment
- Approach: Process development and initial parameters for encapsulation would occur at the MSC (cold box). Once an acceptable procedure was established, the process would be handed off to TA-55 welders. Weld qualification and welding of the bottom end plug would occur at the MSC, while final encapsulation would occur at TA-55. A QA package would be initiated and maintained throughout the process.

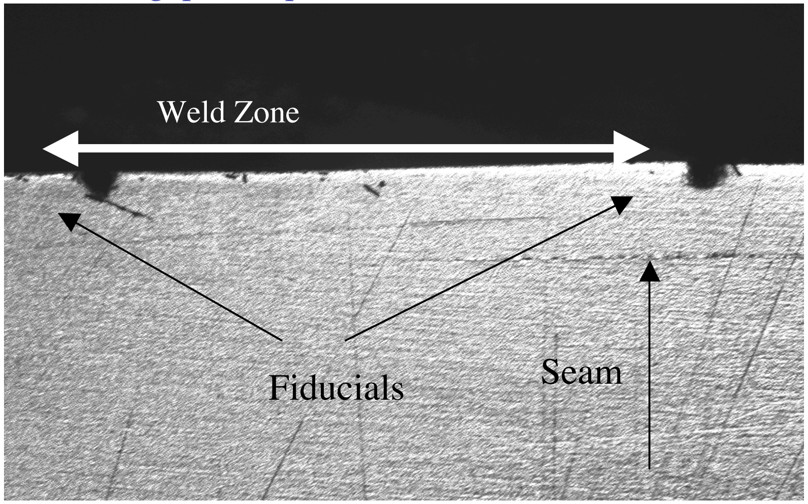
Weld development



Fit: End plugs and tubes had to be machined to tight tolerances. Poor tolerances lead to gaps and poor welds.



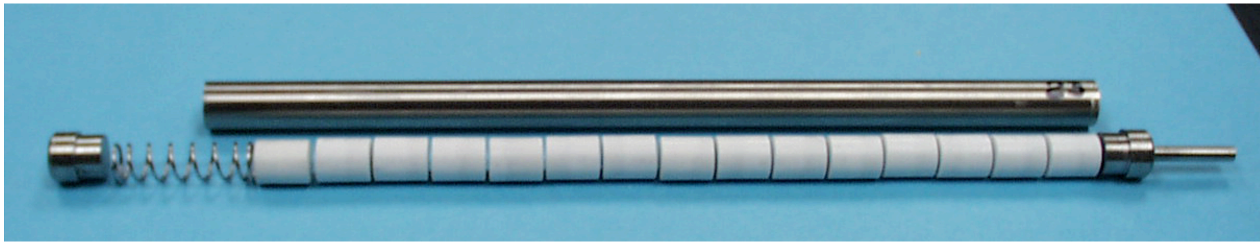
Heat: Power had to be sufficient to produce an acceptable weld without heating pellets to cracking or excess He release from pin.



Specifications: Weld must pass through a ring gauge (0.3825 in.). Welds must not have inclusions or porosity that exceed in diameter 1/3 of the wall thickness, T (T=0.026 in.)

Process Development

- Welding Parameters:
  - -Material: 1/2 OD Zr-4, Zr-4 to spec.
  - -Amperage: 16-32 amps
  - -Pulsing: 3-9 pulses per second
  - -Background: 35-75 % of peak amperage
  - -Rotation: 0.3 -3.2 rpm
- Characterization:
  - -Metallography
  - -Helium Leak Testing
  - -Radiography

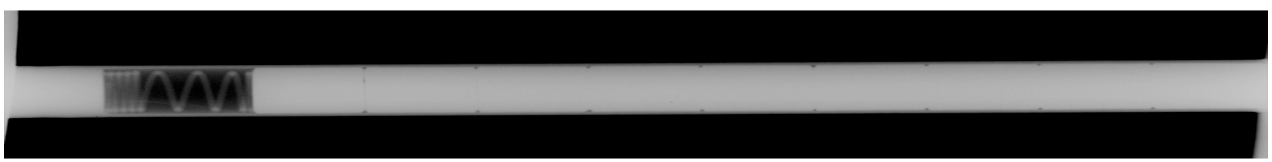


Peak Amperage: 26 Amps
Pulsing: 5 pulses per second
Time at Peak Amp: 35%
Background: 50% of Peak Amps
Rotation: 3.0 rpm

Cold Process: Load spring side end plug into tube, place into base heat sink, add top heat sink, perform first weld. Pass weld and tube through ring gauge and Go/No Go gauge.

Hot Process: Load pin with spring and pellets (using funnel), load closure plug, place into base heat sink, add top heat sink, perform second weld. Pass weld and tube through ring gauge and Go/No Go gauge.

Cold Process
performed at the MSC



Hot Process
performed at TA-55

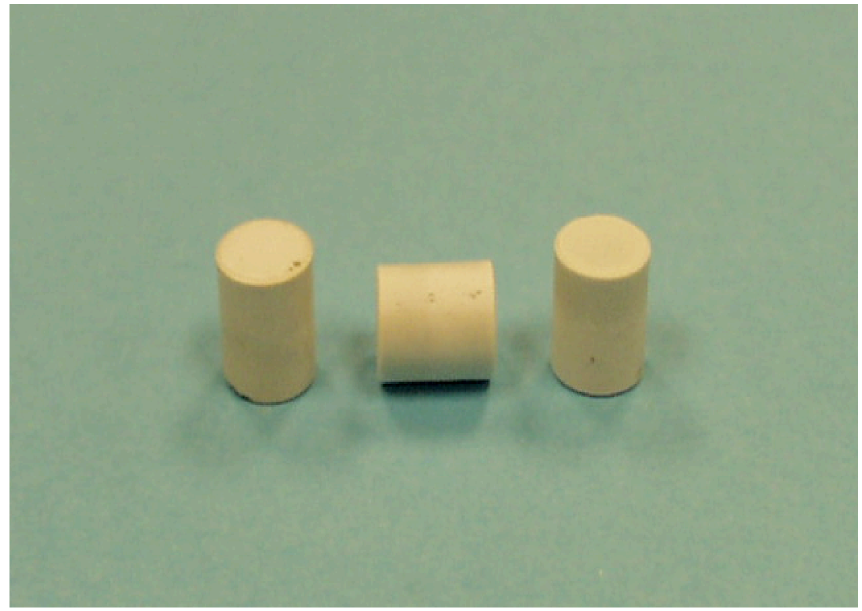
Hafnia Insulator Pellets

- Objective: Anticipation of the potential need for hafnia insulator pellets led to the development of a process for pressing and sintering high density hafnia pellets to final dimensions.
- Constraints:
  - Material: Used stock material (-325 mesh, 99.95% pure)
  - Equipment: Pellets could not be ground within timeframe.
  - Therefore, sintered pellets had to be within tolerances.
  - Only available die was 10.3 mm (pellet diameter $\leq$ 8.33 mm)
  - Temperature: Phase transformation (m$\leftrightarrow$t $\geq$ 1670 ° C)
- Approach: Dimensional and density studies were performed in which the mass, force, and sintering temperatures were varied. Percent shrinkage due to sintering and the relationship between green and sintered densities were examined. A brief experiment involving binders and lubricants was also conducted.

Hafnia Insulator Pellets

Results:

- Highest sintered densities were achieved when pressed at 250MPa (>99.1% T.D.).
- Greatest integrity of pellets was achieved when pressed at 37MPa (>96.7% T.D.).
- Binder and lubricant investigated had no discernable effect on sintering.
- Sintered Pellets were within tolerances when pressed to □49.6% green density and sintered to □96.7% sintered density.
- No evidence of lamination or end capping.
- Process and results are repeatable.



Hafnia pellets, 37MPa, 10.3 mm die

Oxygen Diffusion in Ce-O, U-O, and Pu-O

Use the available free energy of formation of various defect types in CeO_{2-x}.

Completed

Model the diffusivity of oxygen in CeO_{2-x}

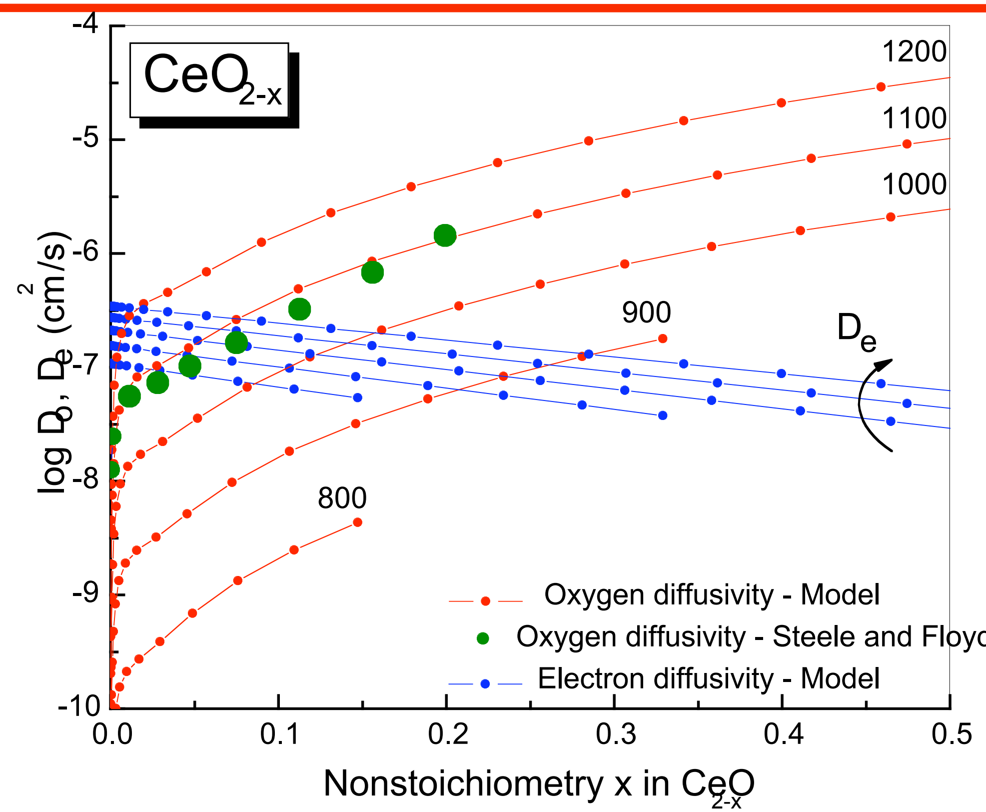
Completed

Determine the free energy of formation of various defect types in PuO_{2-x} and $UO_{2\pm x}$.

In progress

Model the diffusivity of oxygen in PuO_{2-x} and $UO_{2\pm x}$.

In progress



Calculated oxygen diffusivity (red) in non-stoichiometric ceria and electron diffusivity (blue) as a function of non-stoichiometry (x) and temperature (Celsius). Comparison with experimental data[1] (green points).

[1] B. C. H. Steele and J. M. Floyd, Proceedings of the British Ceramic Society, 19, 55 (1971).

Materials Modeling and Simulations for Nuclear Fuels Workshop (MMSNF-1)
June 8-10, 2003, Santa Fe, NM

Fifty participants from U.S.A., U. K., Sweden, and Turkey. See: **www.lanl.gov/mst/nuclearfuels**

Sessions:

- **Programmatic Context**
- **Modeling and Simulation Scales**
- **Thermodynamic Properties**
- **Phase Stability**
- **Thermo-Mechanical Properties**
- **Transport Phenomena**
- **Irradiation Effects**
- **The Impact of Modeling and Simulations on Nuclear Fuels Development**

Summary:

-Modeling and simulations of materials properties must be coupled with the high-level fuel codes, such as FRAPCON/FRAPTAN, TRANS URANUS, TRAC, NITRAF, etc.
-Calculations have to be carefully planed way in advance, to allow for short-tem, medium-term, and long term requirements.
-New methods must be developed to address properties of complex, multi-component systems (nitrides + metals+oxides, composite fuels).
-Modeling properties of fission products (Cs, Sr, He, I, Tc) and their compounds is a priority.
-Better models are necessary to describe thermo-mechanical phenomena such as: thermal fatigue, void formation, and swelling.
-Multi-scale modeling and simulations involve teaming up in developing complex software packages where compatibility and self-consistency play a critical role.
-The models must be validated through experimental work and then used to predict new properties of the materials.
-Given improvements in accuracy and full validation of the methods, simulations based on sound models of materials properties will be part of the fuel qualification process.

Materials Modeling and Simulations for Nuclear Fuels Workshop (MMSNF-2)
November 21, 2003, New Orleans, LA
(contact M. Stan at mastan@lanl.gov)

NNSA

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Summary

- LWR-1
  - PROF-1 pellet production is complete
  - PROF-2, -3 pellet production nearing completion
  - Weld development complete
  - Physical, chemical characterization is underway
  - Hafnia insulator pellets complete
- Other
  - Model of oxygen diffusivity in ceria is complete
  - First MMSNF Workshop was held in July in Santa Fe